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Clinical and Histologic Evaluation of Six Erbium:YAG Lasers for Cutaneous Resurfacing

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Background: **Several erbium:YAG lasers are currently available for cutaneous laser resurfacing. Although different laser systems are purported to produce equivalent laser energies to produce similar laser–tissue interactions, no comparative clinical or histologic studies have been performed to objectively demonstrate their relative efficacies.**
Objective: **The purpose of the present study was to examine the in vivo clinical and histopathologic effects of six different erbium:YAG resurfacing lasers.**
Methods: **A blinded, prospective study using six different erbium lasers (Candela, Continuum Biomedical, HGM, MDLT, SEO, Sharplan/ESC) was performed. The facial halves of 12 patients were randomly resurfaced with one of the six laser systems by using an identical laser technique at 5.0 J/cm². Intraoperative skin biopsies were obtained after each of three laser passes in two patients for blinded histologic determination of tissue ablation level and presence of residual thermal damage. Clinical assessments of reepithelialization rates, severity and duration of erythema, side effects, and degree of clinical improvement were made at 0.5, 1, 2, 4, 12, 26, and 52 weeks postoperatively.**
Results: **Irrespective of the erbium laser system used, complete reepithelialization typically occurred at 0.5 weeks and resolution of erythema was noted within 1–2 weeks postoperatively. A mean clinical improvement of 50% was observed, with photodamaged skin showing greater improvement than scarred skin. The most common postoperative side effect was hyperpigmentation, with all affected patients having either darker skin tones or preceding dermal inflammation. Three laser passes were needed to effect total epidermal ablation when using any one of the erbium:YAG systems.**
Conclusions: **Equivalent clinical and histologic results were seen after each of the six erbium:YAG lasers studied. Erbium:YAG laser resurfacing can be used to significantly improve mild cutaneous photodamage and atrophic scars. Lasers Surg. Med. 24:87–92, 1999.**

Key words: Er:YAG; cutaneous resurfacing; laser; histology

INTRODUCTION

The road to the development of current resurfacing lasers was paved by the revolutionary elucidation of the principles of selective photothermolysis by Anderson and Parrish in 1983 [1]. Carbon dioxide (CO_2) and erbium:YAG lasers are now being used successfully to treat a variety of epidermal and dermal lesions, including rhytides, dyschromias, and scars [2–18]. The high water specificity of these infrared systems accounts for their ability to ablate superficial tissue with minimal thermal diffusion [19–25]. The newest of the two systems, the erbium:YAG laser, has been

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TABLE 1. Patient Characteristics

Patient	Gender	Age (years)	Diagnosis	Skin type
1	F	39	Photodamage	I
2	F	35	Photodamage	II
3	F	45	Photodamage	II
4	F	42	Atrophic scars	II
5	F	49	Photodamage	I
6	M	39	Atrophic scars	III
7	F	60	Photodamage	I
8	F	51	Photodamage	II
9	M	38	Atrophic scars	II
10	F	54	Photodamage	I
11	F	48	Photodamage	II
12	F	21	Atrophic scars	IV

TABLE 2. Random Assignment of Erbium: YAG Laser

Patient	Left facial half	Right facial half
1	Candela	ConBio
2[a]	ConBio	HGM
3	HGM	MDLT
4	MDLT	SEO
5	SEO	Sharplan/ESC
6	Sharplan/ESC	Candela
7	ConBio	MDLT
8	MDLT	Sharplan
9[a]	Sharplan	Candela
10	Candela	HGM
11	HGM	SEO
12	SEO	ConBio

[a]Skin punch biopsies were obtained from the preauricular region after each of three laser passes with all six erbium: YAG laser systems.

touted to be a superior ablative tool because of its higher water absorption coefficient and its limited residual thermal effect in the dermis [26,27]. Its primarily "photomechanical" tissue effect (as opposed to the "photothermal" effect of the CO_2 laser) leads to less coagulative necrosis but also to reduced hemostasis and collagen shrinkage [2].

Despite their relative ability to effect similar clinical results, differences in histologic depths of tissue ablation and residual thermal damage have been shown to exist between different CO_2 laser systems [19,25]. Given innate variations in erbium:YAG technology, one might also expect similar differences to exist between different erbium:YAG lasers. Thus, the present study was designed to evaluate and compare the clinical and histologic responses of skin in vivo to six commercially available erbium:YAG laser systems.

MATERIALS AND METHODS

Twelve patients (two men, 10 women, age = 21–60 years, skin phototypes I–IV) with mild photodamage and/or atrophic scars were enrolled in this blinded, prospective study after informed consent had been obtained (Table 1). No patients who had received isotretinoin within 6 months of study initiation or who had a concomitant cutaneous infection or inflammatory skin condition were included. Patients who had undergone previous facial dermabrasion, phenol peeling, or silicone or collagen implantation were excluded from the study. Other criteria for study exclusion included tanned skin, perpetual ultraviolet light exposure, and unrealistic expectations.

Patients were randomly assigned to receive treatment to facial halves with two of six erbium:YAG laser systems on a rotating basis (Table 2): Candela (Wayland, MA), Continuum Biomedical (Dublin, CA), HGM (Salt Lake City, UT), MDLT (Palo Alto, CA), Schwartz Electro-Optics (Orlando, FL), and Sharplan/ESC (Needham, MA). Patients and clinical evaluators were blinded to the lasers used in each case. All of the laser procedures were performed by a single laser operator with equivalent laser parameters (5 J/cm^2). Light intravenous sedation with midazolam (Versed, Roche Laboratories, NJ), propofol (Diprivan, Stuart Pharmaceuticals, DE), and fentanyl citrate (Sublimaze, Akorn, Inc., Abita Springs, LA) was administered by a nurse anesthetist.

Laser operating protocol consisted of the adjacent placement of spots or scans, with approximately 30% overlap over the assigned facial half. The first pass was delivered in a horizontal manner, the second pass in a vertical orientation, and the third pass in a diagonal pattern so that no "skip" areas or "stripes" were evident. Partially desiccated tissue was removed with saline-soaked gauze after the completion of each laser pass.

A 3-mm skin punch biopsy was obtained in two patients in the preauricular region before and after each of three passes with the six laser systems (total = 19 biopsies, including one untreated "baseline" tissue sample). The resultant tissue defects were closed with 6-0 nylon sutures.

During the postoperative period, patients used an "open technique" consisting of frequent applications (every 1–2 hours) of Aquaphor ointment (Beirsdorf, Inc., Norwalk, CT) and ice-water compresses. On the fourth day (0.5 week) postoperatively, patients were clinically evaluated and their wounds were cleaned with dilute hydrogen peroxide and acetic acid compresses. By the first

postoperative week and after full reepithelialization had occurred, all patients had been placed on a twice daily application of Hydrotone cream (ICN Pharmaceuticals, Costa Mesa, CA) and were instructed to avoid sun exposure. Prophylactic antiviral medications (Famciclovir 250 mg BID) and intraoperative antibiotics (Cephlaexin 1 g) were prescribed.

Clinical evaluations and sequential photographs were performed at 0.5, 1, 2, 4, 12, and 26 weeks postoperatively. One-year follow-up examination was also made in nine patients. Two physicians blinded to study protocol independently rated the degree of healing as demonstrated by completion of reepithelialization and the severity and duration of erythema by using an appropriate numeric scaling system: 0 = none, 1 = minimal, 2 = partial, 3 = complete for degree of reepithelialization and 0 = none, 1 = mild, 2 = moderate, 3 = severe for the severity and duration of erythema. Clinical improvement 4, 12, and 26 weeks after erbium:YAG laser resurfacing was determined by an assessment of the reduction in rhytides and scars with the following numeric scale: 0 = <25% improvement, 1 = 25–50% improvement, 2 = 50–75% improvement, 3 = >75% improvement. Side effects and complications of the procedure were observed for and recorded at each postoperative visit.

Tissue biopsies were preserved in 10% formalin, embedded in paraffin, and processed with hematoxylin and eosin. A board-certified dermatopathologist performed blinded histopathologic evaluation of the specimens by using standard light microscopy and an ocular micrometer. The depth of tissue ablation and the degree of residual thermal damage were measured after each of three passes with the six laser systems and compared with adjacent, untreated skin (baseline).

RESULTS

Similar intraoperative tissue reactions were observed in all laser-treated facial halves. Laser-irradiated skin appeared pale pink in color, with pinpoint areas of bleeding. Minimal to no discernible collagen shrinkage was evident with any system.

Complete reepithelialization occurred in all laser-treated facial halves in 10 patients (83%) at 0.5 week and in all patients by 1 week. Minimal erythema was observed in most patients (75%) at 0.5 week. Mean duration of erythema was 1.2 weeks (range = 1–2 weeks). No differences in severity or duration of erythema were seen between different laser systems or facial halves.

TABLE 3. Clinical Results and Side Effects

Patient	Clinical rating[a]	Side effects
1	2	
2	1	
3	1	Dermatitis, hyperpigmentation
4	1	Acne exacerbation
5	2	
6	1	Hyperpigmentation
7	2	
8	2	
9	1	
10	2	
11	2	Herpes reactivation, hyperpigmentation
12	1	Hyperpigmentation

[a]Clinical rating scale: 0 = <25% improvement, 1 = 25–50% improvement, 2 = 50–75% improvement, 3 = >75% improvement.

Hyperpigmentation was seen in four patients (25%) at the fourth postoperative week (Table 3). Two of these same patients had a preceding inflammatory skin condition: one with herpes simplex virus reactivation at postoperative day 3 and one with contact or allergic dermatitis at 1 week. One patient suffered exacerbation of acne 1–2 weeks postoperatively that required the use of oral antibiotics and elimination of occlusive topical creams.

On average, a clinical improvement score of 1.5 was seen that corresponded to approximately 50% clinical improvement (range = 25–75%; Fig. 1A–D). Mildly photodamaged skin (mild facial dyspigmentation and rhytides) had better average scores (1.8) than did atrophic scars (1.0).

Histologic evaluation of tissue biopsies showed partial epidermal ablation (2–6 μm) after one or two passes when using any of the six laser systems. Three laser passes effected total epidermal ablation (8–12 μm) without measurable residual thermal damage in the dermis (Fig. 2A–D).

DISCUSSION

The present results confirm the major differences between CO_2 and erbium:YAG lasers, namely the differences in ablation depths and tissue effects. Whereas the thermal effects of the CO_2 laser produce a relatively wide zone of coagulative necrosis affecting hemostasis and collagen shrinkage [19–25,28], the photomechanical tissue effect of the erbium:YAG results in less thermal

Fig. 1. Mild facial photodamage (rhytides and dyspigmentation) in a 35-year-old woman (patient 2) before (**A**) the Continuum Biomedical erbium:YAG laser was used on the right facial half and the HGM laser on the left at 5.0 J/cm^2 (three passes). The same patient at 0.5 week (**B**), 1 week (**C**), and 4 weeks (**D**) postoperatively shows 25–50% clinical improvement (rating = 1).

diffusion, coagulative necrosis, hemostasis, and collagen shrinkage [26,27]. Also, in contrast to the different CO_2 lasers, where differences exist between systems in terms of level of tissue ablation and residual thermal damage [25], different erbium:YAG lasers systems do not produce measurably different tissue effects.

Postoperative evaluation of reepithelialization rates (mean = 0.5 week) in erbium laser-irradiated facial halves were equivalent as assessed by visual inspection. The severity and duration of postoperative erythema were also similar between differently treated facial halves.

The relatively speedy postoperative recovery times seen after erbium laser treatment (0.5 week vs. 7–10 days with CO_2) would be expected to incite fewer side effects and complications, but this was not the case because the rates of hyperpigmentation (33%), herpes simplex reactivation (8.3%), dermatitis (8.3%), and acne exacerbation (8.3%) were similar to those reported after CO_2 laser resurfacing [29–31]. It is interesting to note that half of the patients with hyperpigmentation had a preceding dermal inflammation (e.g., herpes simplex reactivation, dermatitis), whereas the other half had darker skin phototypes (e.g., III, IV), suggesting particularly susceptible patient groups for the development of hyperpigmentation.

Although the indications for CO_2 and erbium:YAG laser resurfacing are similar, the present study was designed to limit clinical and histologic evaluation to those patients with mild photodamage or atrophic scarring to provide statistical significance to the results. The fact that complete epidermal ablation without measurable residual thermal damage was seen after three passes when using the six different erbium:YAG laser systems at 5 J/cm^2 accounted for the limited (50%) average clinical improvement seen. Erbium:YAG laser resurfacing of more severe cutaneous photodamage or scarring with similar treatment parameters thus would produce even less favorable results because of increased dermal fibrosis and reduced tissue water

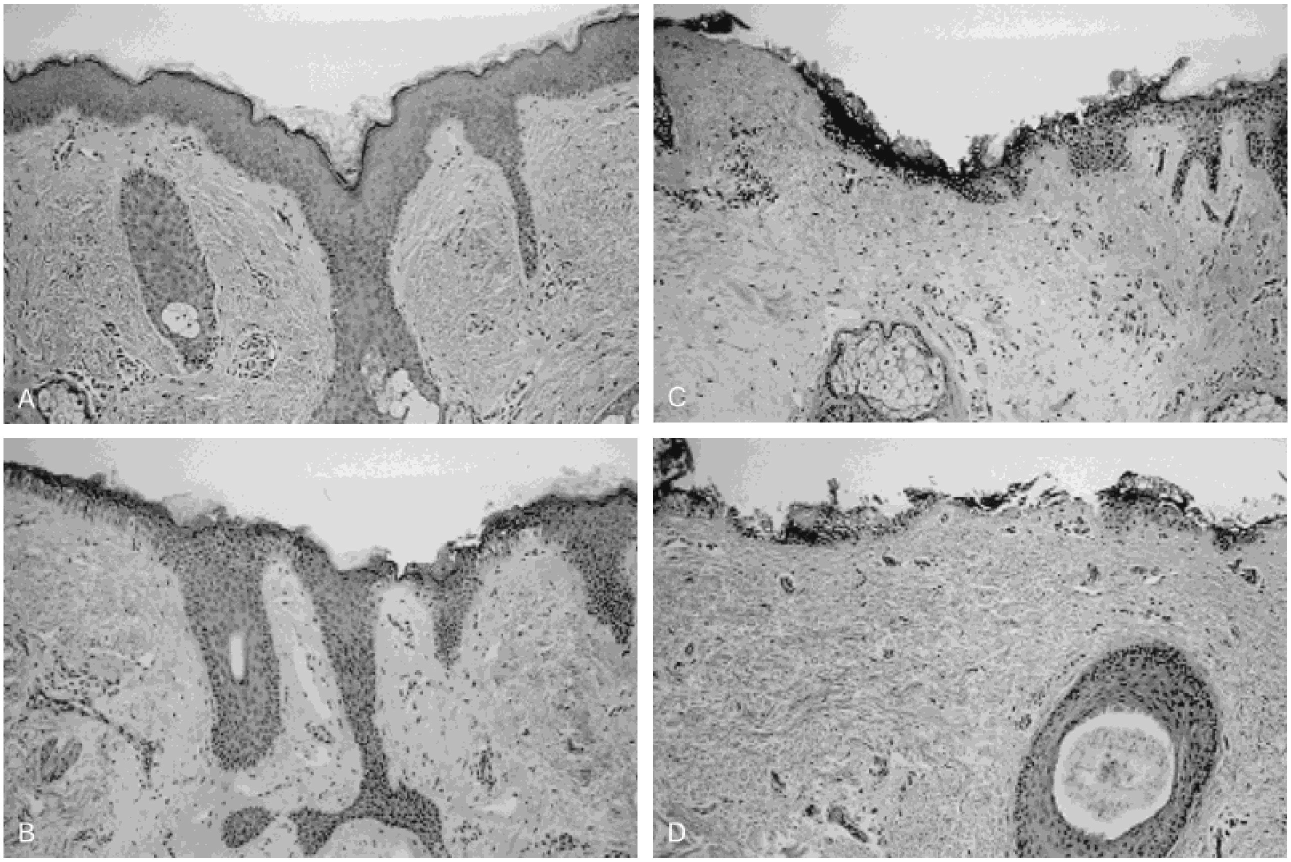

Fig. 2. Histopathologic results (hematoxylin and eosin stain) after erbium:YAG laser resurfacing: baseline/before treatment (**A**) and after each of three passes at 5.0 J/cm^2. Partial epidermal ablation was seen after one (**B**) and two (**C**) passes, and full epidermal ablation was achieved after three passes (**D**). Equivalent depths of tissue ablation and lack of residual thermal damage in the dermis were observed in all six erbium laser systems studied.

content. However, the use of higher (10–15 J/cm^2) fluences (currently available with a few of the systems studied), application of additional laser passes, and/or use of larger spot sizes would be expected to enhance results.

No further clinical improvement or worsening was noted 1 year after the erbium laser resurfacing procedure, which is in contrast to cutaneous CO_2 laser resurfacing, where continued clinical (and histologic) changes have been reported up to 12–18 months postoperatively [32]. In particular, delayed hypopigmentation (6–12 months) and further collagen remodeling (with progressive clinical improvement) have been noted in patients undergoing CO_2 laser treatment [2]. The fact that these were not observed in the present study suggest that a photothermal laser effect may be required not only to produce immediate collagen shrinkage but also to provide a matrix for continued collagen deposition that recapitulates the shortened form [33].

Because strategies for cutaneous laser resurfacing have continued to evolve since the procedure became widespread in the mid-1990s, an in vivo study such as the present one is particularly important to provide laser surgeons with objective criteria on which to base their patient and laser selection decisions. In general, the use of any one of the six erbium:YAG laser systems (employing identical laser parameters and operative technique) will produce equivalent clinical and histologic results. Based on the present results, it is recommended that cutaneous laser resurfacing with the erbium:YAG laser at 5.0 J/cm^2 be used for mild photodamage and atrophic scars and that CO_2 laser resurfacing be considered for moderate to severe cutaneous involvement because of its inherent ability to effect tissue shrinkage and enhance collagen remodeling.

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